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# Soil Moisture in Numerical Weather Prediction

*Soil Moisture Active-Passive  
(SMAP) Mission*

Arlington, 9 July 2007

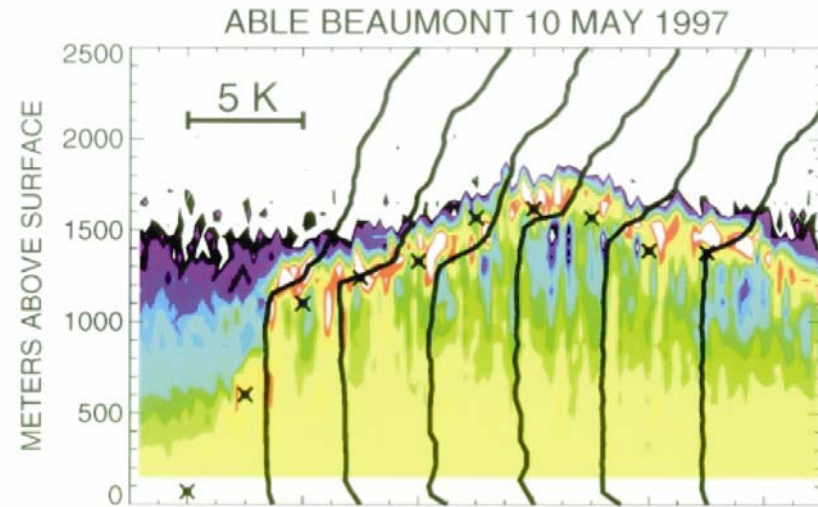
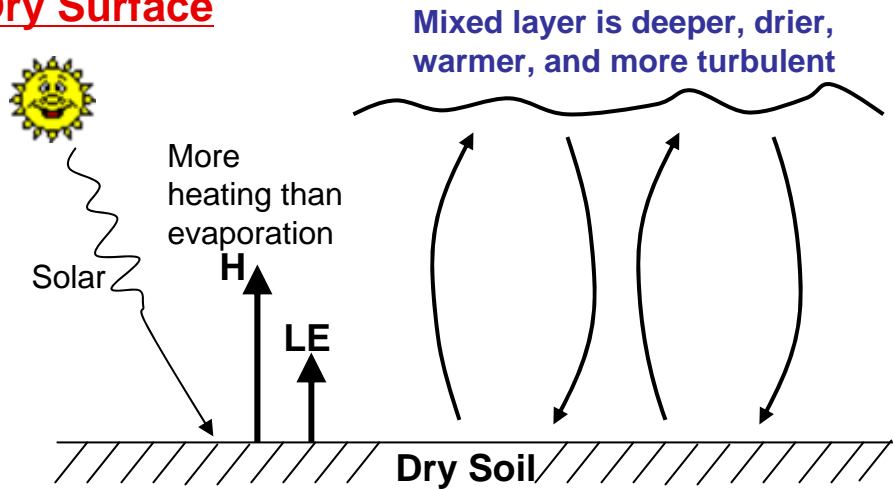
**STEPHANE BELAIR**

**Meteorological Research Division**

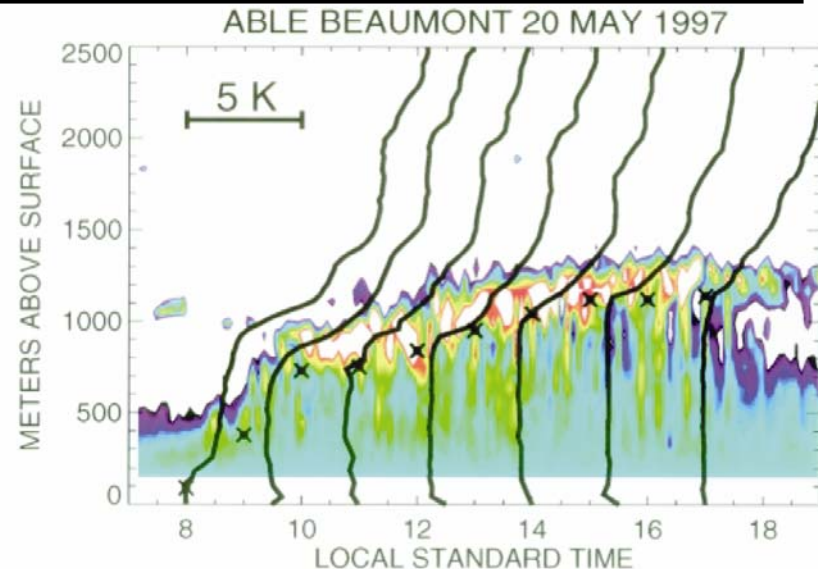
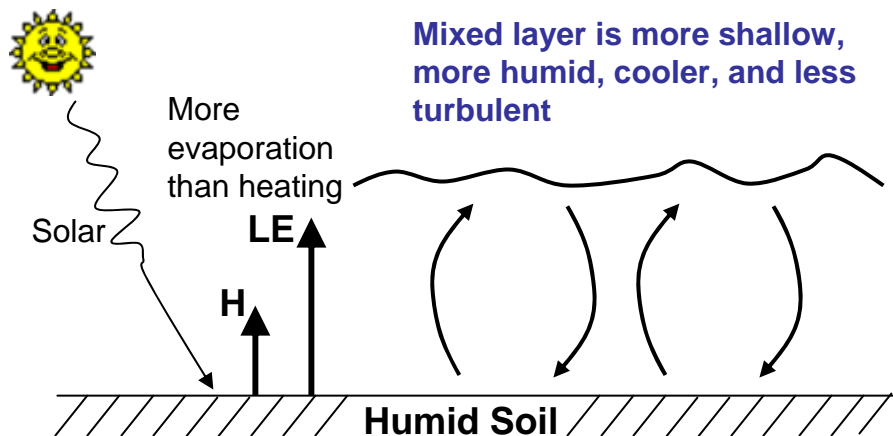


# Soil Moisture and the Well-Mixed Boundary Layer

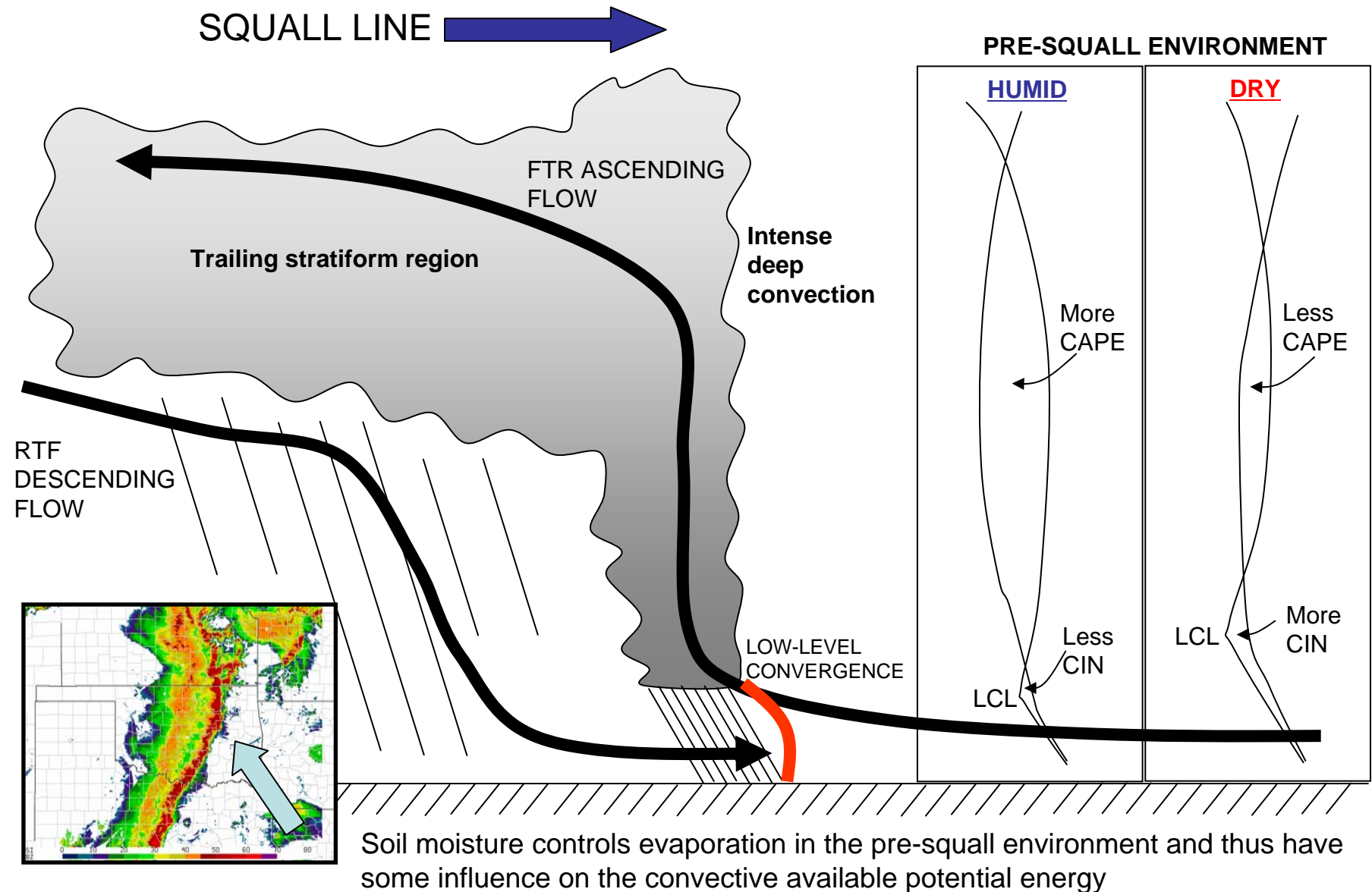
## Dry Surface



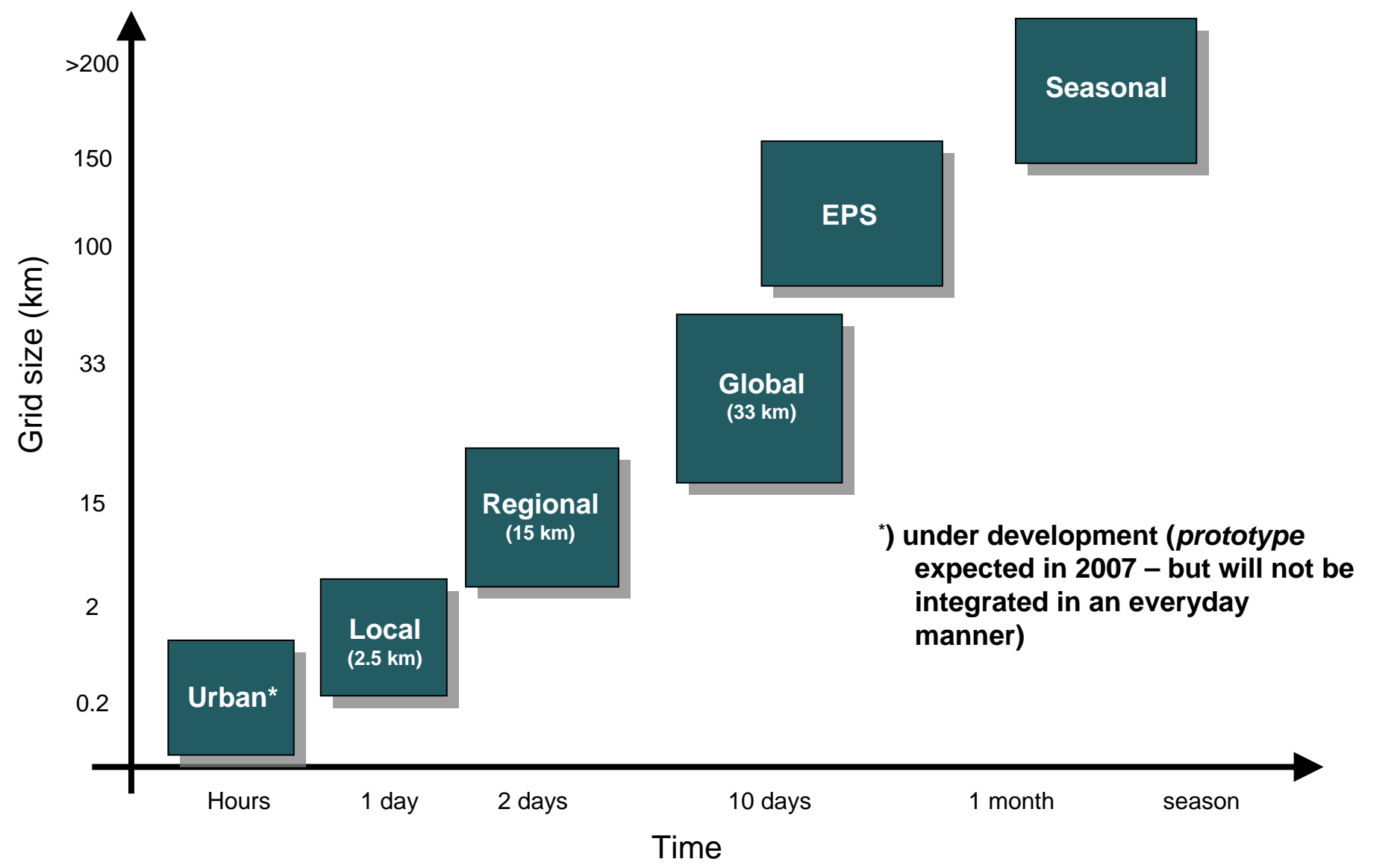
## Moist Surface



# Soil Moisture and Severe Precipitation Events Over Land



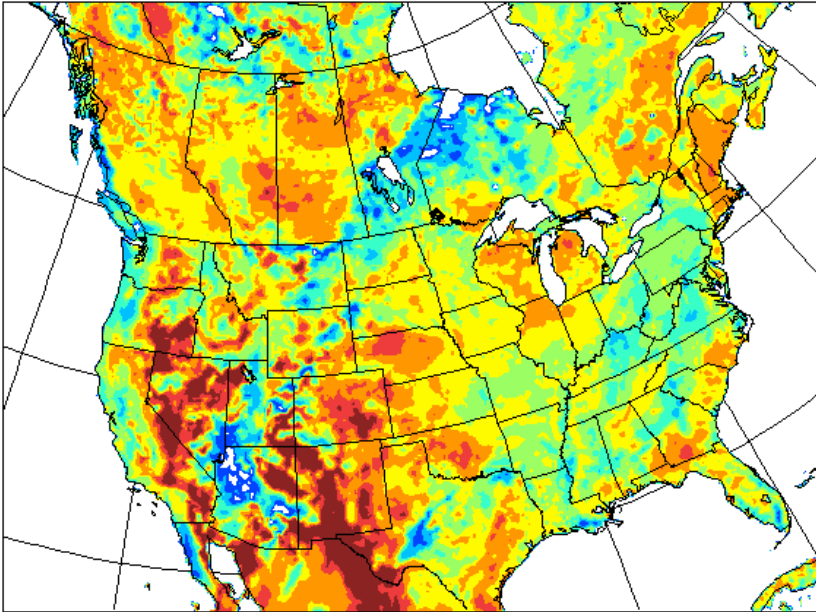
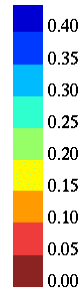
# Operational Forecasting Suite at the Canadian Meteorological Centre



# Impact of Soil Moisture on Short-Range Numerical Weather Prediction

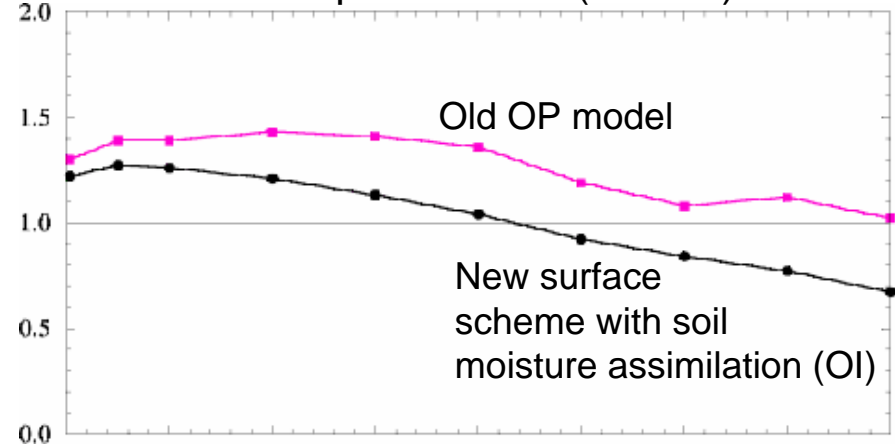
Near surface soil moisture

$\text{m}^3\text{m}^{-3}$



(valid at 1200 UTC 22 October 2004)

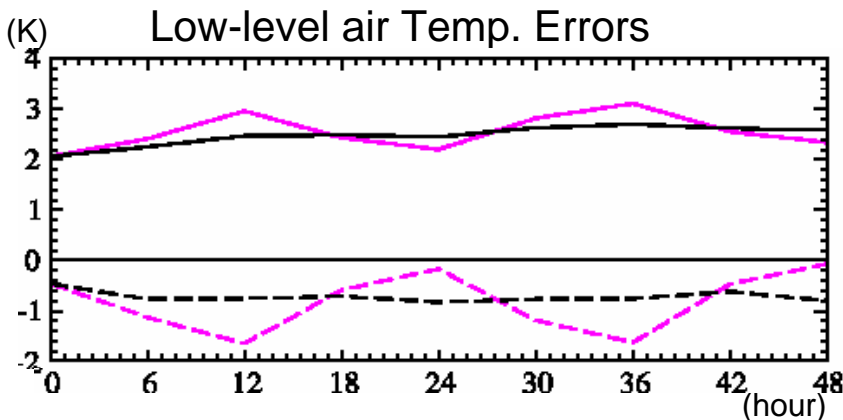
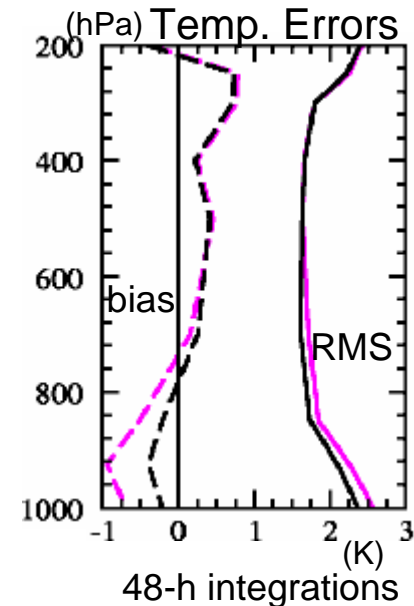
Precipitation bias (24-48h)



Better soil moisture resulted in significant improvements for:

- Low-level air temp. and humidity
- Diurnal cycle of the PBL
- Precipitation biases

NOTE: mostly in summer

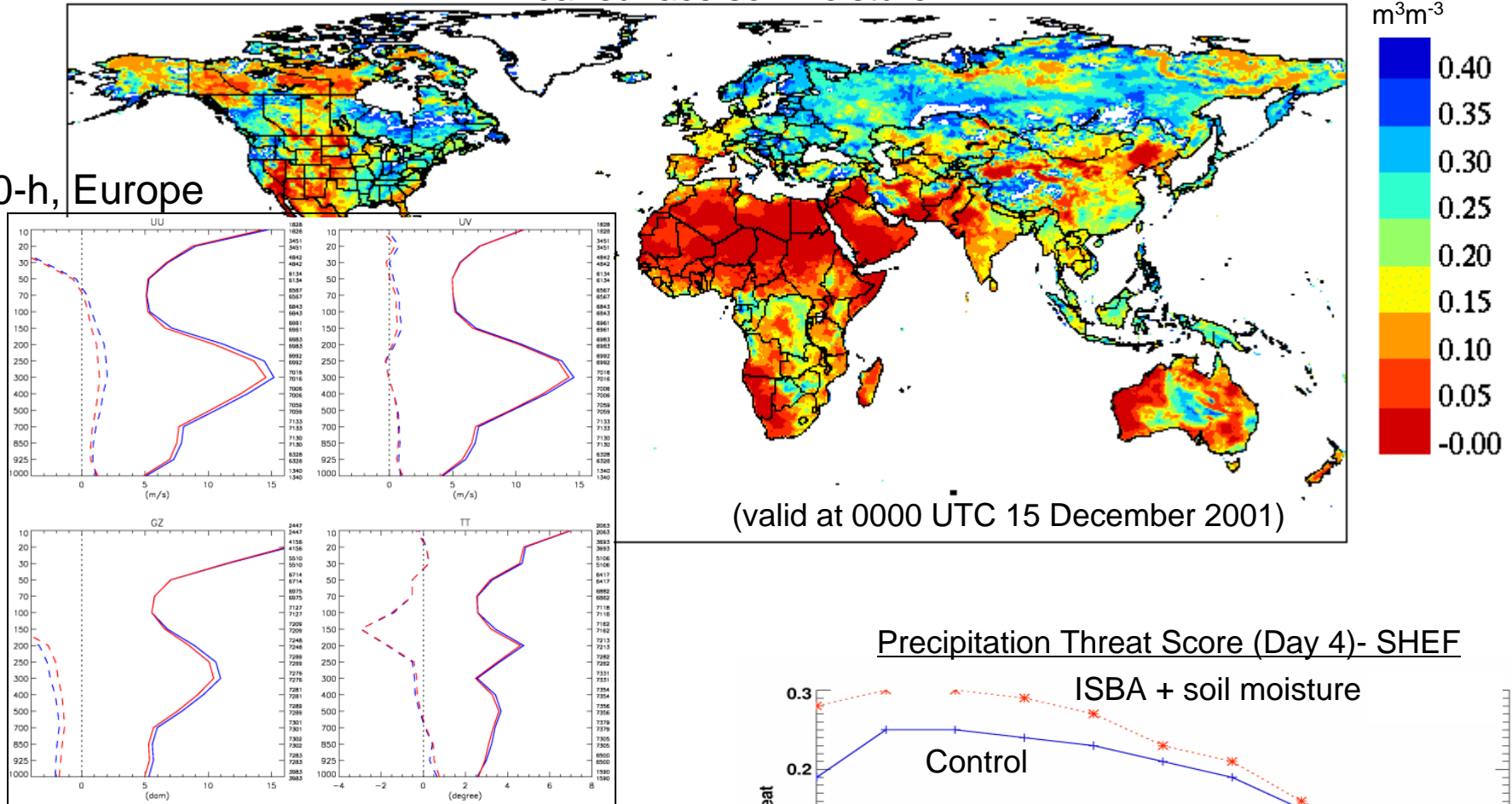


(Bélair et al.)

# Impact of Soil Moisture on Medium-Range Numerical Weather Prediction

Near surface soil moisture

120-h, Europe

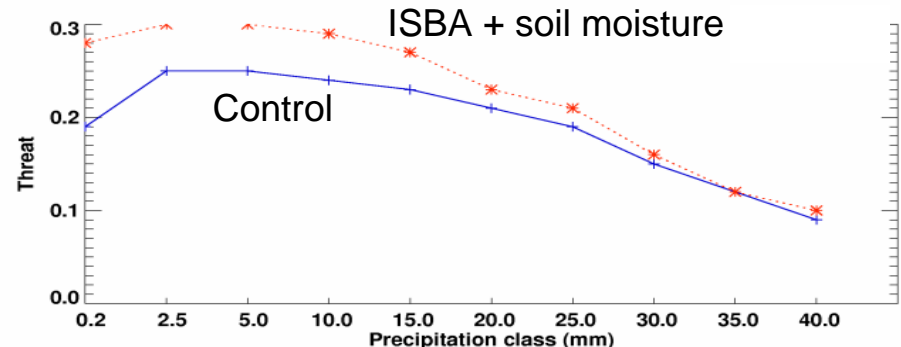


(valid at 0000 UTC 15 December 2001)

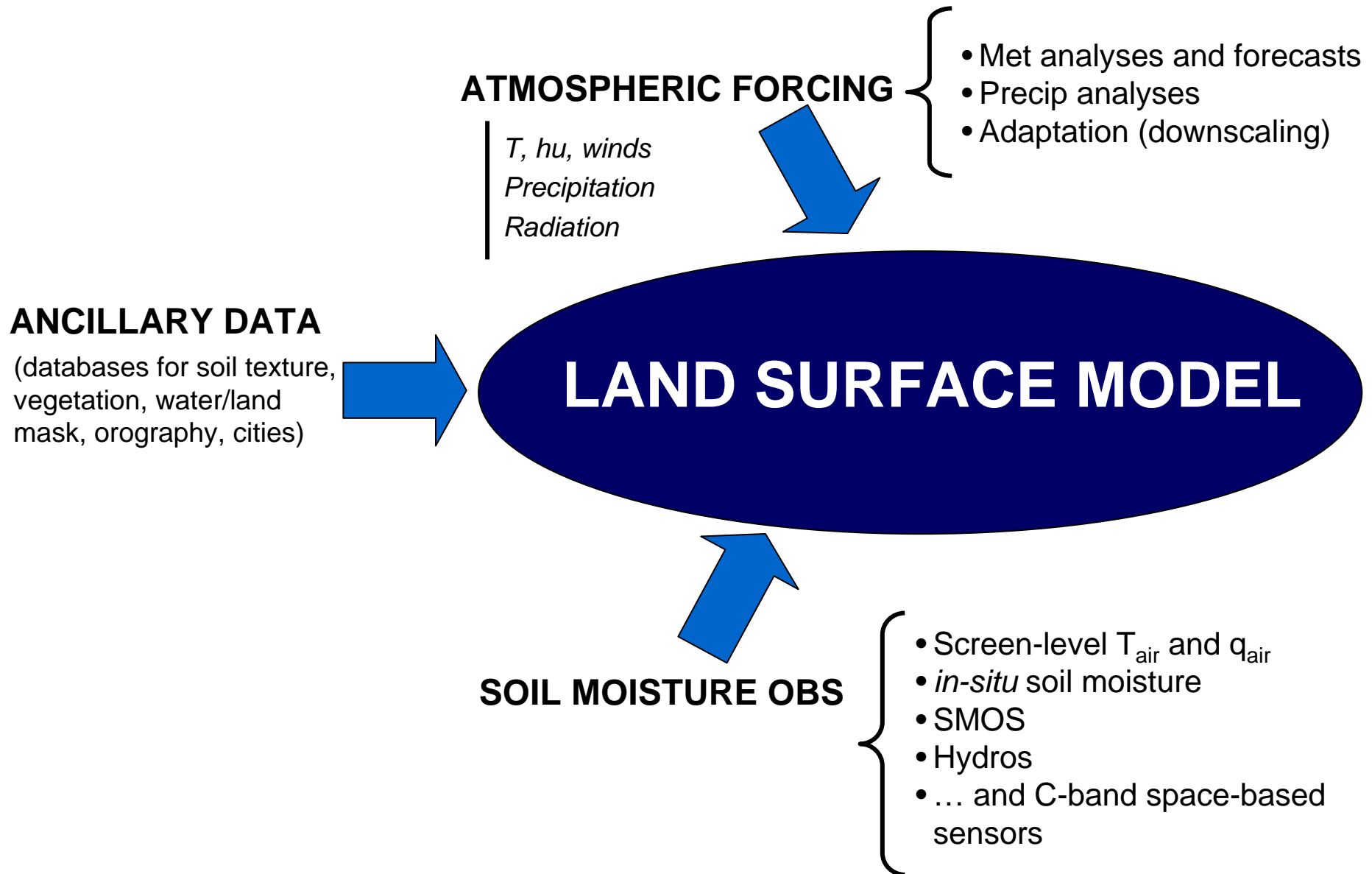
Has been implemented in the global forecasting system (31 October 2006).

(*Bélair et al.*)

Precipitation Threat Score (Day 4)- SHEF



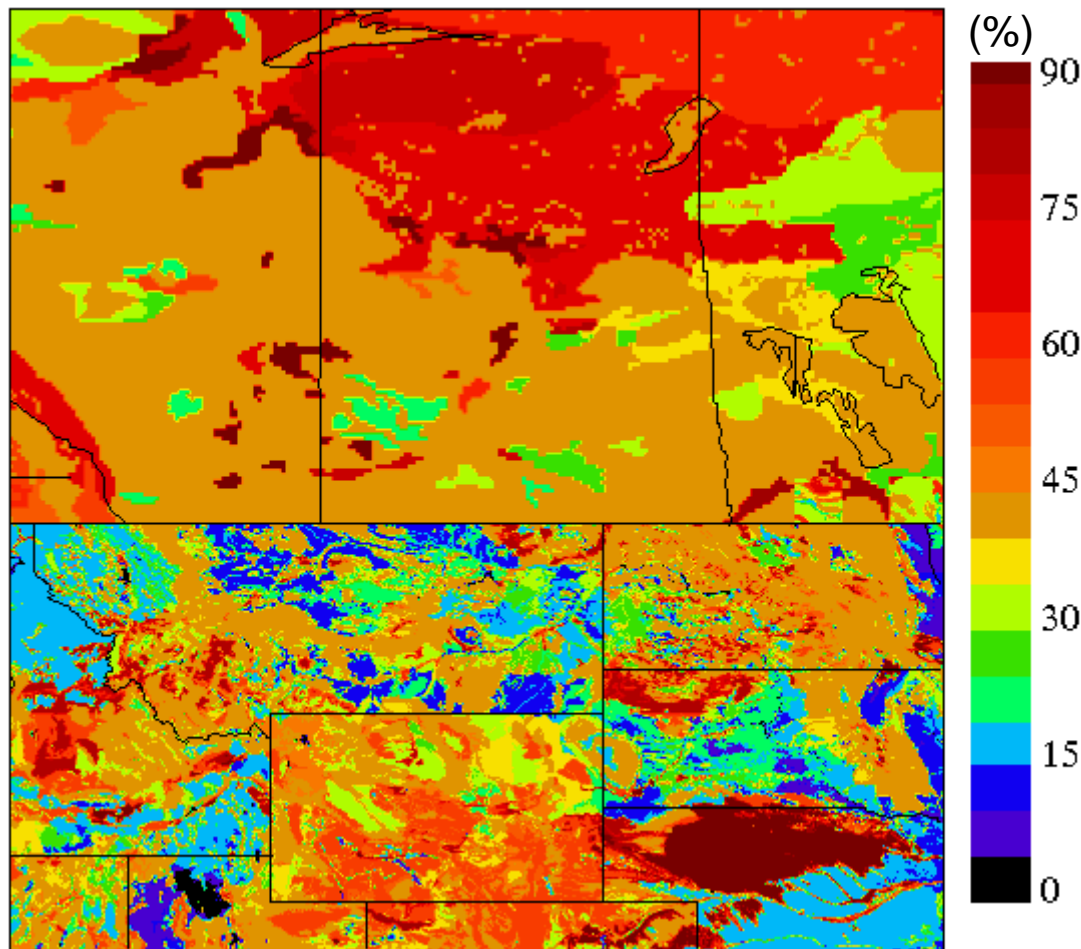
# Soil Moisture Data Assimilation





# Soil Texture

## Sand Fraction



*In Canada, the soil texture is defined in this case using a database from the Food and Agriculture Organization (FAO)*

*In the US, the soil texture is obtained from the US State Soil Geographic database (STATSGO).*



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# The Canadian Precipitation Analysis (CaPA)

Surface obs

Satellite obs

Model outputs



Correction of a first guess field using a weighted average following:

$$x_a^j = x_b^j + \sum_{i=1..N} w^{ij} (y_o^i - y_b^i)$$

The background (first guess) is given by our best model products

The weight matrix is given by

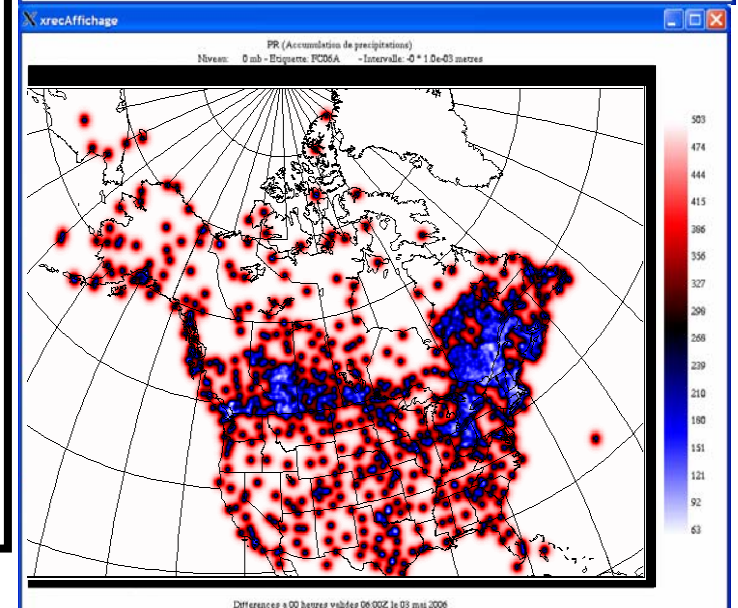
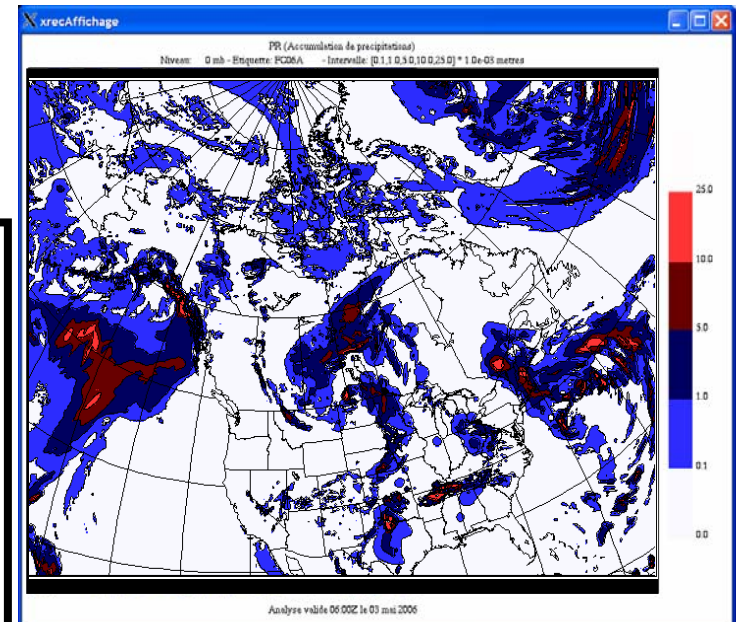
$$W = (B + O)^{-1} b$$

where B and O are the background and observations error covariance matrices, given by

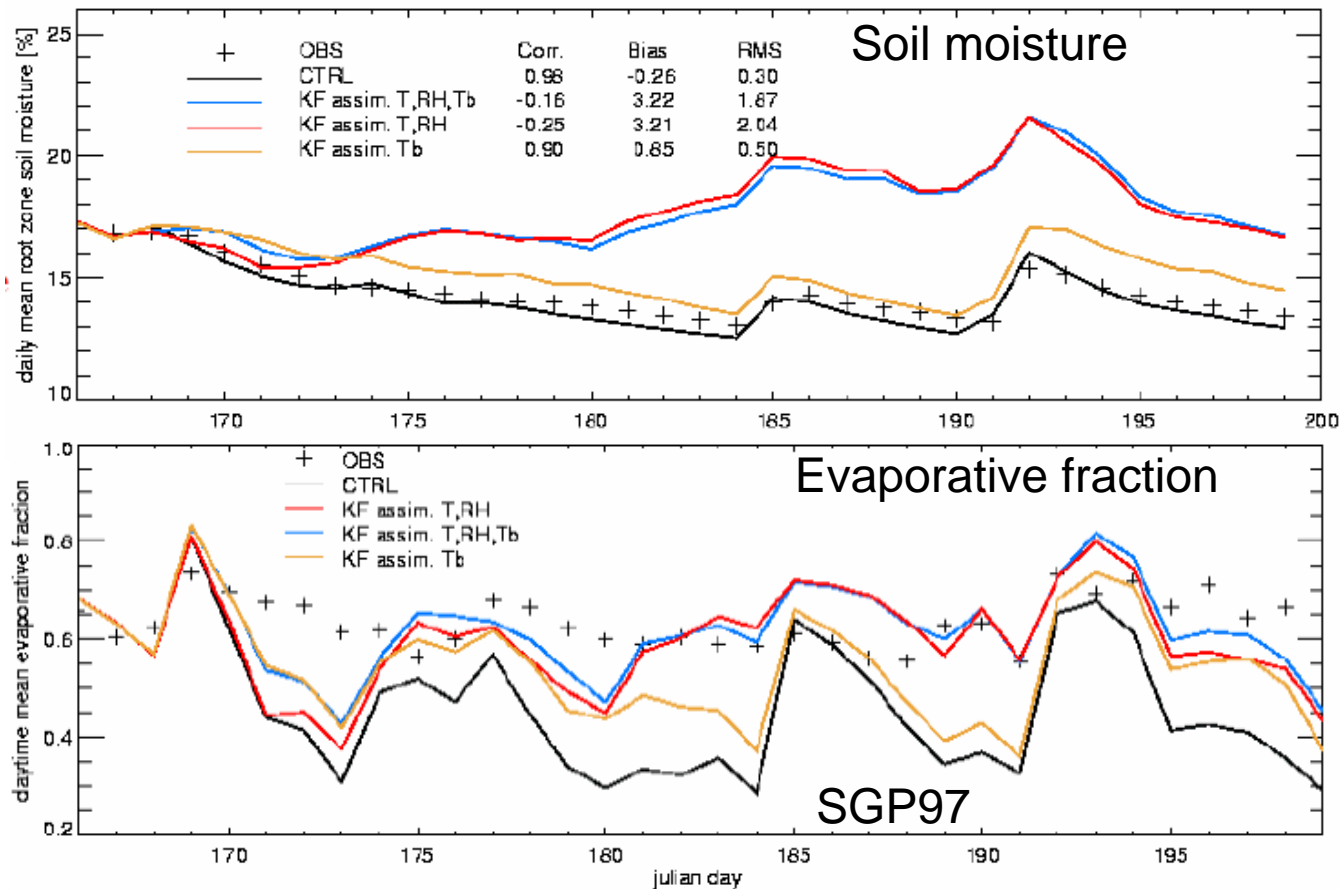
$$B^{ij} = \sigma_b^2 \times \left(1 + \frac{r_{ij}}{L}\right) \times \exp\left(-\frac{r_{ij}}{L}\right)$$

$$O^{ij} = \sigma_o^2 \times \delta_{ij}$$

(Fortin, Mahfouf, Brasnett, Gagnon)



# Soil Moisture vs Surface Fluxes



**Assimilation of Tb leads to good representation of soil moisture**

**But it does not necessarily lead to better surface fluxes**

**Conversely, the assimilation of screen-level air characteristics leads to better surface fluxes, but soil moisture is far from the observed values.**

(From Ettema, ECMWF/ELDAS workshop on land surface assimilation, 2004)

# Soil Moisture in NWP: Issues and Concerns

- Soil moisture is of crucial importance for NWP, at all scales and ranges.
- For NWP, getting surface fluxes right is more important than getting soil moisture right. But future applications in hydrology requires that NWP model be good for *both* surface fluxes *and* soil moisture.
- In Canada's current NWP system, the soil moisture analysis compensates for other errors (e.g., forcing, land surface). As these errors are gradually reduced, a real soil moisture analysis becomes achievable.
- Soil moisture observations and surface fluxes are required to verify (and improve) NWP model's performance (also need all the information to drive the land surface schemes)

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